HYDROLOGY AND BIOGEOCHEMISTRY OF AN URBAN MITIGATION WETLAND

Senior Thesis

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By

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Abstract

The hydrology and biogeochemistry of the urban mitigation wetland located at the Olentangy River Wetland Research Park (ORWRP) in Columbus, Ohio was studied during the summer months of 2015. The freshwater resource is susceptible to nutrient contamination due to industrial and agricultural runoff. These nutrients in high enough concentrations can pose a health hazard and also have been linked to the hypoxia of the Gulf of Mexico. Wetlands have been created along rivers throughout the Mississippi watershed to reduce and trap these pollutants. Excess floodwater flows into the wetlands, where the floodwater undergoes biogeochemical transformations and then is reintroduced back into the river. The water in the wetland at the ORWRP was tested from June 11th, 2015 to July 16th, 2015 for anion concentrations (nitrate, sulfate, chlorine), dissolved organic carbon concentrations, the amount of dissolved oxygen present in the water column, and pH. The wetland was effective at reducing the concentration of nitrate that was introduced into it after three flooding events. Sulfate did not undergo any biogeochemical transformations during the study, but evidence suggests that the wetland may act as a sulfate sink. Chloride also did not undergo any biogeochemical transformations, but showed evidence of the hydrological connection between the Olentangy River and the wetland. The water from the Olentangy River had low dissolved organic carbon concentrations, high dissolved oxygen concentrations, and also more acidic pH. After each of the three flooding events, the water in the wetland concentrations of dissolved organic carbon decreased, the concentrations of dissolved oxygen increased, and the water in the wetland became more acidic. The urban mitigation wetland located at the ORWRP is effective at mitigating the amount of contaminants that are introduced into it by floodwater from the Olentangy River and the wetland ecosystem is healthy and thrives based off its concentrations of dissolved organic carbon, dissolved oxygen, and its pH.

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I would also like to thank the Wilma H. Schiermeier Olentangy River Wetland Research Park for providing the field site. Without their generosity in letting me spend the summer there conducting my research and collecting samples, this project would not have been possible. Without the help of Dr. Sue Welch and Ms. Kathy Welch my field samples would never have been analyzed. I am very grateful for their time and patience in teaching me how to properly run and test my field samples. The nutrient analyzer was acquired under the grant NSF GEO EAR 0744166 and the ion chromatograph under NSF GEO EAR IF 1342632. I am also grateful for the National Science Foundation providing the equipment.

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Introduction

The freshwater resource is very susceptible to contamination and pollution. Many nutrients that are important to the overall health of aquatic ecosystems may become contaminants at high concentrations. Some of these nutrients are applied deliberately to support agricultural practices as fertilizer and these nutrients can then seep into the groundwater or flow over the land surface and make their way into our streams, lakes, and oceans. This nutrient loading can contaminate our drinking water resource and can lead to illness or death for many organisms, including humans. For example, the Mississippi River, the largest river in the United States, discharges into the Gulf of Mexico (Fig. 1). The Mississippi River watershed is the fourth largest in the world, and includes parts of 31 states and two Canadian Provinces (National Park Service, 2016). The watershed measures approximately 1.2 million square miles, covering about 40% of the lower 48 states (National Park Service, 2016). Major rivers, such as, the Ohio River, the Missouri River, and the Arkansas River, are within the Mississippi River catchment.

Figure 1. The Mississippi River watershed with hypoxic zone indicated (oval) (National Park Service, 2016).

The area in the Gulf of Mexico surrounding the Mississippi River Delta is susceptible to a severe hypoxia. The amount of dissolved oxygen present in the water column in the Northern area of the Gulf of Mexico is so low that the water no longer supports aquatic organisms. One of the main causes of this hypoxic zone in the Gulf of Mexico is the eutrophication of the ocean water due to the delivery of nutrients from within the Mississippi River catchment to the Gulf of Mexico. The influx of nutrient rich water increases the rate of primary production and phytoplankton populations proliferate. When these phytoplankton eventually die, and bacteria start to decompose them, the availability of dissolved oxygen in the water is depleted, resulting in such low levels of dissolved oxygen that aerobic aquatic organisms cannot survive.

To combat this eutrophication and associated hypoxia in the Gulf of Mexico, mitigation wetlands have been created along rivers in the Mississippi River basin. These wetlands are fed primarily by floodwater that deposits sediment and contaminants into the wetlands. "Filtered" water then seeps back from the wetland into the stream (Neubauer, et al., 2005; Fink and Mitsch, 2007; Zhang and Mitsch, 2007). Wetlands are also beneficial because they provide habitats that serve as nurseries for fish and other life, flood storage capacity, reduction of public health threats such as nitrate contamination of drinking water, and improved water quality (Mitsch et al., 2013).

Columbus, Ohio was placed under a drinking water advisory during the summer of 2015 due to high concentrations of nitrate in the municipal drinking water supply (Arenschield, 2015). The advisory targeted pregnant women and infants younger than six months old because they may be susceptible to methemoglobinemia, a condition that results in a reduction in the bloods ability to carry oxygen. Periods of high rainfall during the spring season coincide with agricultural fertilizer application in Ohio and rainfall flushes more fertilizer and agricultural runoff into nearby streams, rivers, and watersheds increasing the concentration of nitrate in surface water during this time of the year. Creating mitigation wetlands in areas susceptible to high nitrate contamination will help reduce the effects of agricultural fertilizer application.

The purpose of this study is to investigate the biogeochemical function of a mitigation wetland in Columbus, Ohio, an urban setting that is prone to potentially harmful nutrient pulses to surface waterways. Specifically, we examine the wetland's hydrologic connection to a nearby river and the biogeochemical cycling of carbon and nitrogen in the wetland in order to evaluate its effectiveness as a strategy to mitigate against nutrient pollution in the river.

Field Site and Methods

Field Site

The Wilma H. Schiermeier Olentangy River Wetland Research Park (ORWRP) is a long-term, large-scale aquatic research facility located in Columbus, Ohio and is administered by the Ohio State University. The facility is located on 52-acres of land and is home to two experimental wetland basins, 1) bottomland hardwood forest, and 2) an oxbow wetland, which is the focus of this study.

The 3-ha created oxbow wetland is situated adjacent to the Olentangy River, separated by a bottomland hardwood forest in urban Columbus, Ohio (Fig. 2). The oxbow was excavated in 1999 to replicate the natural habit that will be found at an oxbow lake within the floodplain of the Olentangy River in an effort to restore the floodplain habitat to a more natural state. The Delaware Dam, located in Delaware, Ohio, approximately 30 miles north of the ORWRP, regulates flow in the Olentangy River. Water from the Olentangy River enters the created oxbow wetland by a check valve located at the northern tip of the wetland and flows back into the Olentangy River by gravity through an outflow control weir at the southern tip of the wetland, approximately 300 m down gradient of the inflow.

The wetland only receives water from the Olentangy River when the water level in the river reaches a certain elevation. Once the water level is high enough, the check valve is opened and river water floods the wetland. This is significant because the ecosystem is dependent upon water from the river. The wetland flourishes during the “wet” seasons of spring and summer, but will dry out during the “dry” seasons of fall and winter. The Columbus area received abnormally high rainfall during summer 2015. The monthly precipitation for June 2015 was 2.71 inches greater than the average. The monthly precipitation for July 2015 was 0.62 inches greater than the average (Weatherunderground). The delivery of nitrate to drinking water sources via overland flow or shallow groundwater flow as a result of this high level of precipitation resulted in the nitrate drinking water advisory that affected Columbus, Ohio, during June 2015 (Arenschield, 2015).

Figure 2. Undated aerial photo of Wilma. H. Schiermeier Olentangy River Wetland Research Park.

Sample Collection

Water samples were collected daily from the wetland from June 11th, 2015 to July 16th, 2015. On days when heavy rainfalls were expected, samples were collected more frequently to better document the wetland's response to increasing Olentangy River water levels.

All water samples were collected in duplicate in pre-rinsed (three times with wetland water) amber glass bottles. One sample was collected for dissolved oxygen content, and was immediately analyzed. The other sample was filtered through a 0.45 µm pore size cellulose nitrate filter paper under light vacuum pressure with a hand pump and Nalgene filter tower. The upper chamber of the filter tower was rinsed three times with wetland water, and the lower chamber was rinsed three time was filtrate prior to collecting samples for pH, major ion, and dissolved organic carbon (DOC) analyses, as described below.

The created oxbow wetland has a depth gauge installed to measure the water level for the wetland, and this was recorded for every sampling. A sample water depth recording was also taken to record how deep the water was at the specific sampling location using a wooden meter stick. The discharge data for the Delaware Dam was used as a proxy for the Olentangy River water level.

Analyses

Dissolved Oxygen:

The dissolved oxygen concentration of an unfiltered wetland water sample was determined on site, less than five minutes after collection, by a modified Winkler method using a dissolved oxygen test kit (Model OX-2P; HACH, Loveland, Colorado). Once the sample was collected, 2 ml manganese sulfate and 2 ml alkali-iodide-azide reagent was added to the sample and inverted several times until the powders were dissolved. Once the powders were dissolved, the resulting floc settled to the bottom of the bottle. At this time 2 ml sulfuric acid was added. The sample was again inverted and the floc will dissolve. One full measuring tube of sample was separated and 0.01 N sodium thiosulfate solution was added by titration. Once the solution turned to clear, the number of drops added equaled the amount of dissolved oxygen present in (mg/L).

pH:

An aliquot of filtered wetland water was analyzed for pH using a Fisher Scientific Accumet portable pH/ORP (Model number AP110). A two-point calibration was performed using 7.0 and 4.0 pH standards prior to analysis daily.

Major Anions:

Each sample taken from the wetland was also tested for major anion concentration (fluoride (F^-), chloride (Cl^-), bromide (Br^-), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), and sulfate (SO_4^{2-})) using a Dionex ICS -2100 ion chromatograph. Filtered water samples were stored in prerinsed (three times with filtrate) Whatman scintillation vials. The analytical method used is described by Welch et al. (1996).

Dissolved Organic Carbon:

An aliquot of filtered wetland water (precumbusted GF/F glass fiber filter paper housed in a precombusted glass filter tower) was stored in sterile (combustion at 480 C for eight hours) borosilicate amber glass vials for subsequent analysis by Skalar SAN++ flow-injection nutrient analyzer. The manufacturer provided the analytical method. Six standards were used and the dissolved organic carbon concentrations were 1, 2, 10, 20, and 50 parts per million respectively.

RESULTS

Hydrologic connection between the Olentangy River and Oxbow Wetland

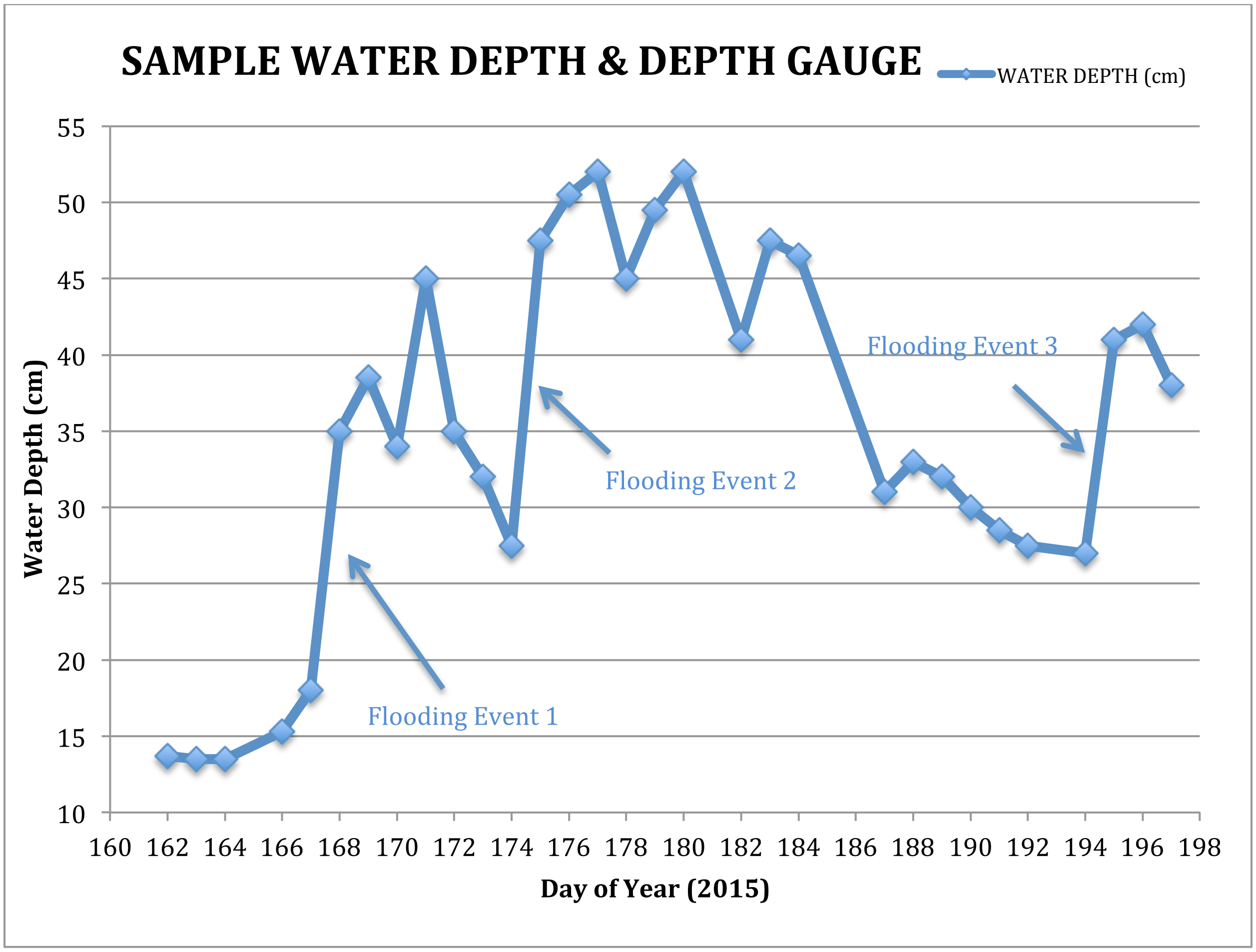

Figure 3. Wetland water level at sample location and installed depth gauge.

The wetland water depths measured at the sampling site and the measurements taken at the installed depth gauge are equal to each other (Fig. 3). The water level in the wetland was at the same elevation at these two different locations. The wetland experienced three main flooding events during the study (Fig. 3). Flooding event 1 occurred between Julian days 167 and 168 and corresponded to an increase in water level of 17 cm. Flooding event 2 occurred between Julian days 174 and 175 and corresponds to an increase in water level of 20 cm. Flooding event 3, which can be partially attributed to a rain event, occurred between Julian days 194 and 195 and corresponds to an increase in wetland water level of 14 cm.

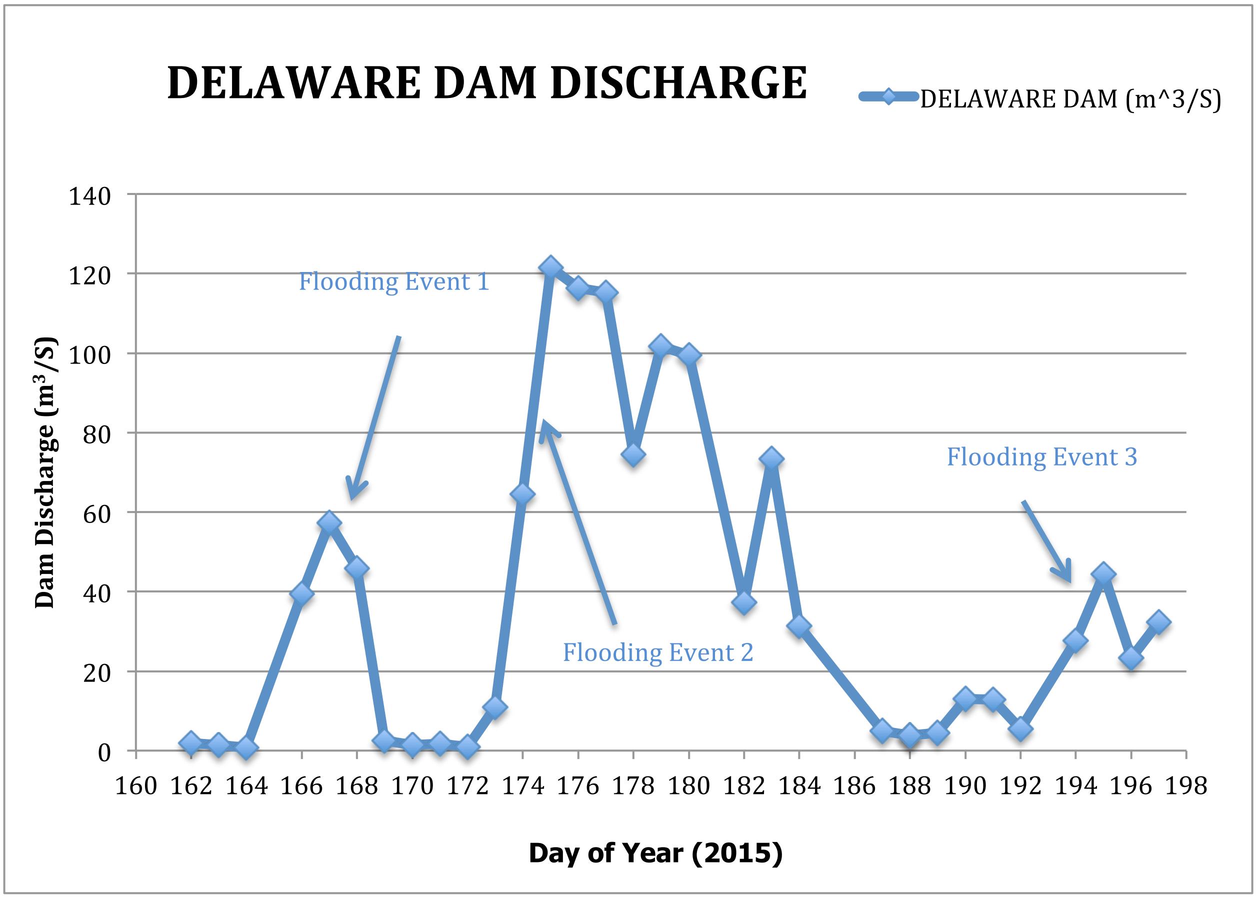

Figure 4. Delaware Dam discharge values

These three main flooding events are also reflected in the discharge record for the Delaware Dam (Fig. 4). Each flooding event in the wetland is preceded by an increase in the volume of water released from the Delaware Dam. Prior to flooding event one, which occurred between days Julian days 167 and 168. The Delaware Dam increased water discharge from 0.71 m^3s^{-1} on day 164 to 57.20 m^3s^{-1} on day 167. Flooding event 2, which occurred on days 174-175, was preceded by an increase in discharge from 10.96 m^3s^{-1} on day 173 to a maximum of 121.48 m^3s^{-1} on day 175. Flooding event 3, which occurred on days 194-195, saw an increase in discharge from 5.38 m^3s^{-1} on day 192 to 44.46 m^3s^{-1} on day 195.

Anion Concentrations

Of the anions analyzed here, only Cl^-, NO_3^-, and SO_4^{2-} fluctuate or are present in the wetland and are presented here.

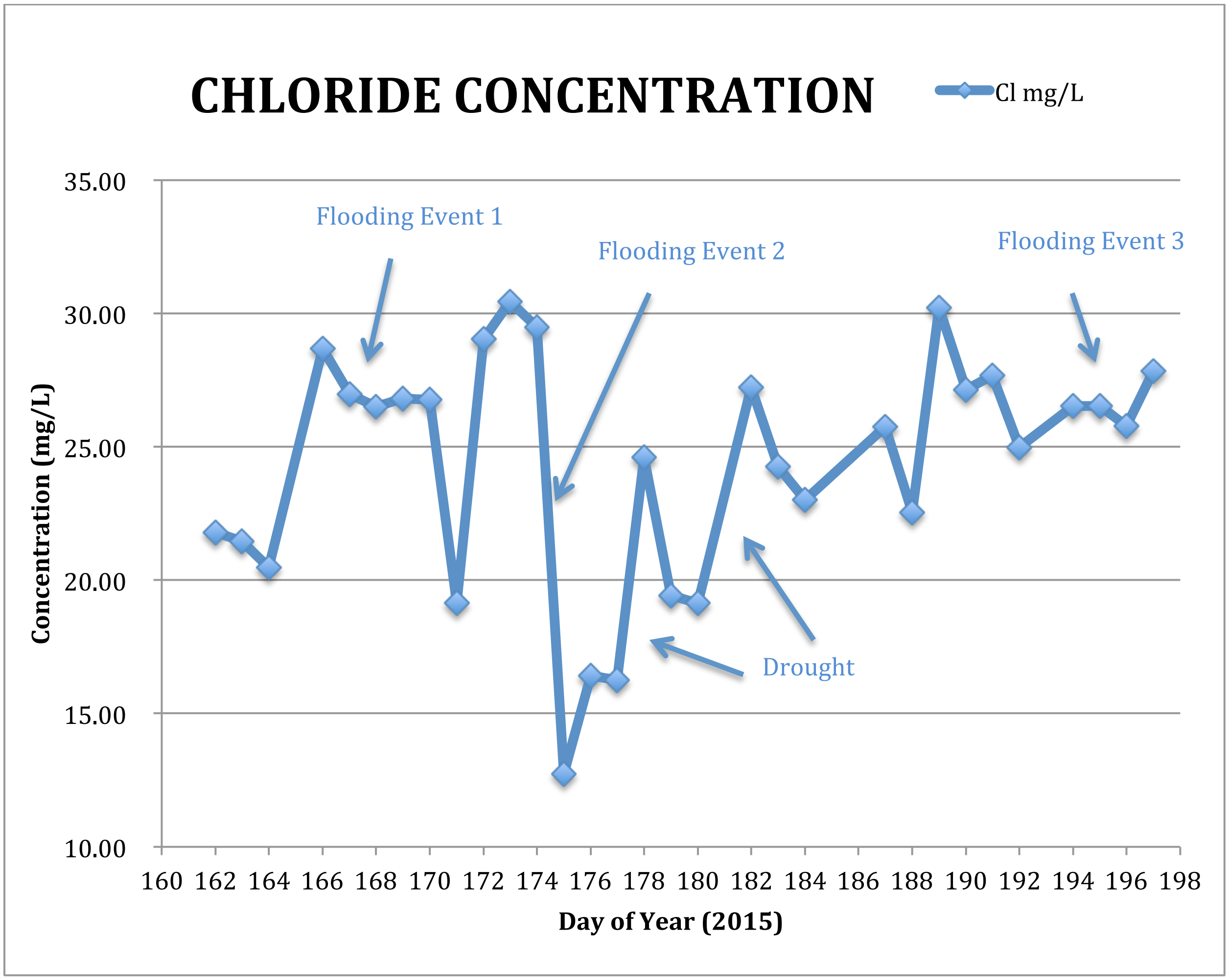

Figure 5. Chloride concentrations for ORWRP from June 11th, 2015 to July 16th, 2015.

During each of the three flooding events, the concentration of Cl^- decreases, especially after flooding event 2 (Fig. 5). After flooding event 2 the concentration of Cl^- decreases from 29.48 mgL^{-1} to 12.74 mgL^{-1}. When flooding events were not occurring and the wetland received relatively short water intake (drought) the concentrations of Cl^- increase.

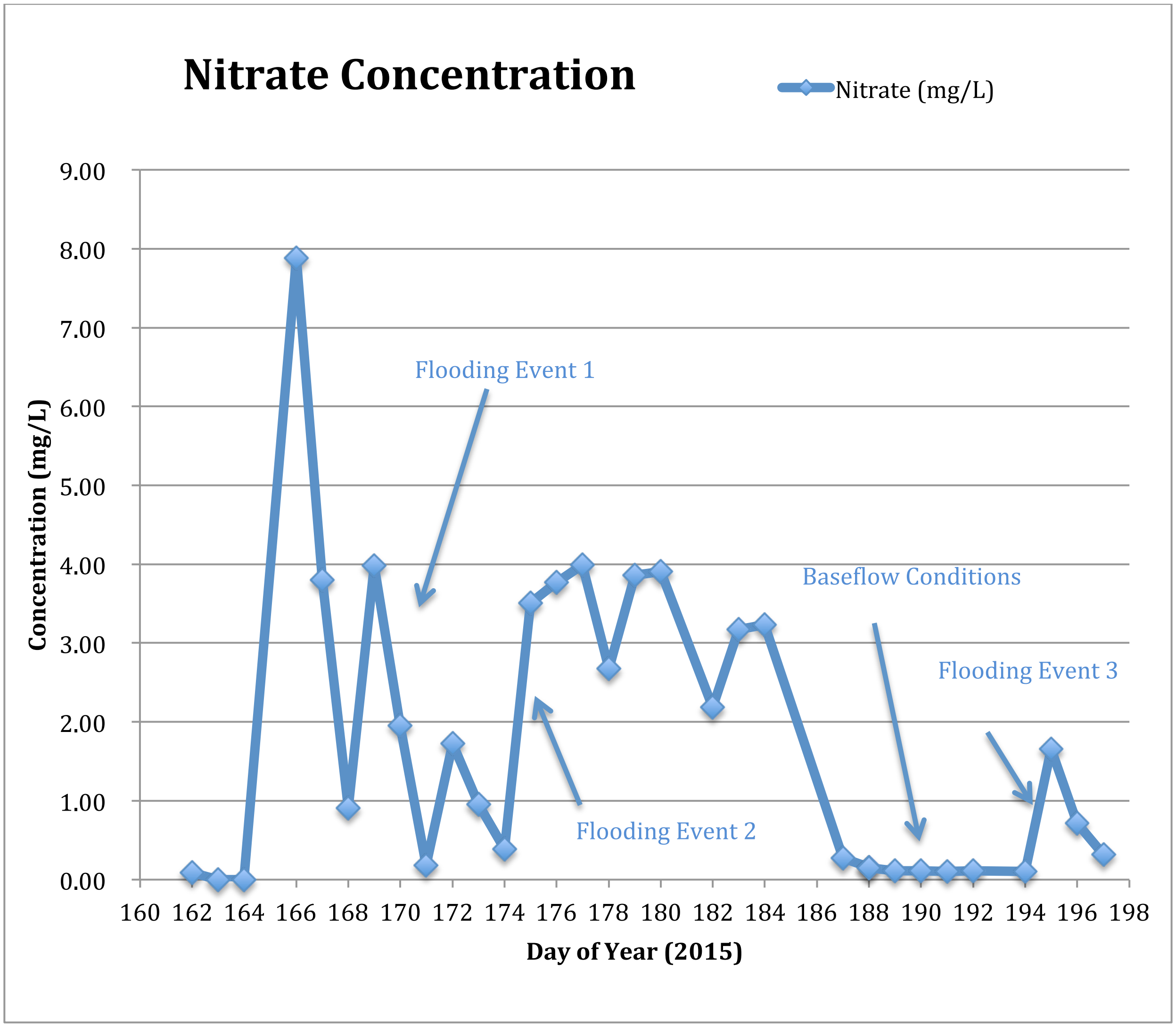

Figure 6. Nitrate concentration for ORWRP from June 11th, 2015 to July 16th, 2015.

In the absence of flood conditions (referred to here as baseflow conditions; eg. Day 188-194) the concentration of NO_3^- in the wetland water is low, fluctuating between 0.16 and 0.10 mgL^{-1}. During flood events, as the water level in the wetland rises, the concentration of NO_3^- also rises (e.g., Days 174-175 and Days 194-195). After each flooding event, an increase in nitrate concentration is shown. After each flooding event has subsided, the concentration of NO_3^- decreases towards baseflow conditions.

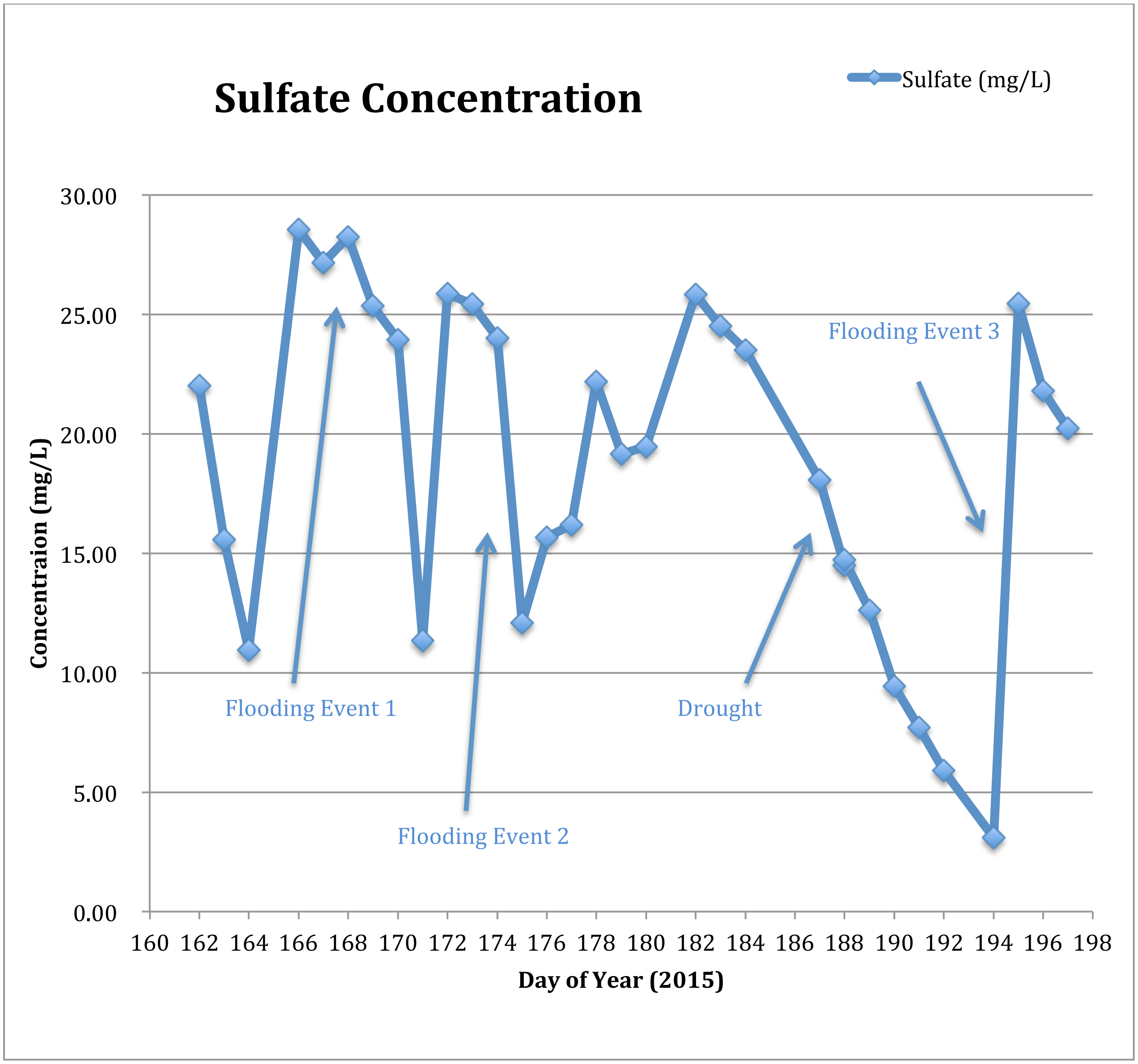

Figure 7. Sulfate concentration for ORWRP from June 11th, 2015 to July 16th, 2015

The first two flooding events resulted in a decrease in SO_4^{2-} concentration (Days 167-168 and Days 174-175), while the third flooding event resulted in a three-fold increase in SO_4^{2-} concentration (Days 195-195). A "drought" occurred from day 184 to day 194, and the wetland water level decreased from 46.5 cm to 27 cm (Fig. 3) coinciding with a decrease in SO_4^{2-} concentration from 23.50 mgL^{-1} to 3.09 mgL^{-1}.

Dissolved Organic Carbon Concentrations

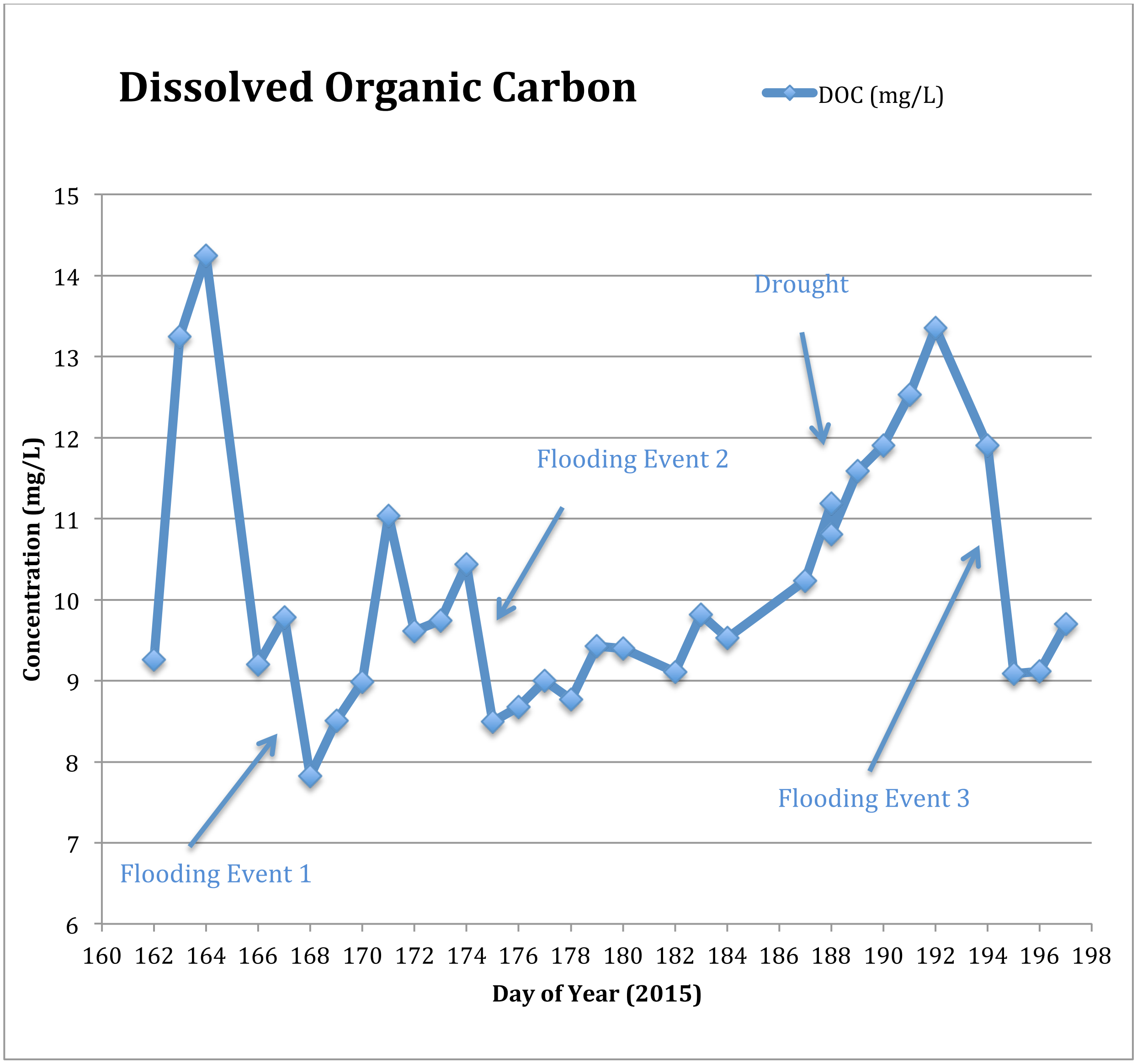

Figure 8. Dissolved organic carbon concentrations for ORWRP.

After each of the three flooding events a decrease in the concentration of dissolved organic carbon was recorded (Fig. 8). During periods of "drought" the concentrations of dissolved organic carbon continually increase until the next flooding event occurs.

Dissolved Oxygen Concentrations

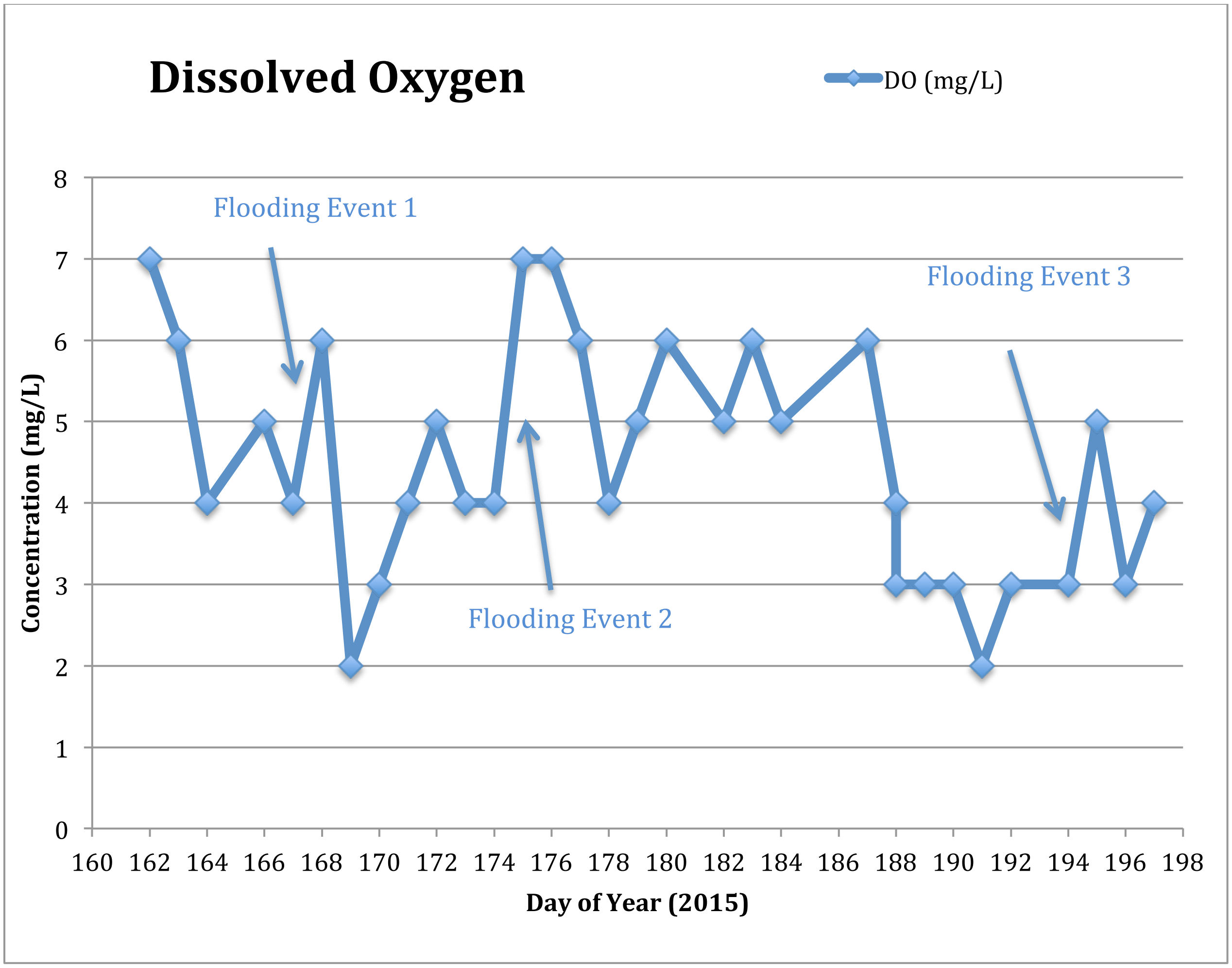

Figure 9. Dissolved oxygen concentrations for ORWRP from June 11th, 2015 to July 16th, 2015.

For most of the record, dissolved oxygen (DO) ranges between 7 mgL^{-1} and 4 mgL^{-1}, expect for after day 188, when DO decreases to 3 mgL^{-1}. The concentration of DO remains at 3 mgL^{-1}, until flooding event 3 (Days 194-195). After each of the three main flooding events, there is a spike in the concentration of dissolved oxygen (Fig. 9). After flooding event 1 the concentration of dissolved oxygen increased from 4 mgL^{-1} to 6 mgL^{-1}. After flooding event 2 the concentration of dissolved oxygen increased from 4 mgL^{-1} to 7 mgL^{-1}. After flooding event 3 the concentration of dissolved oxygen increased from 3 mgL^{-1} to 5 mgL^{-1}.

pH

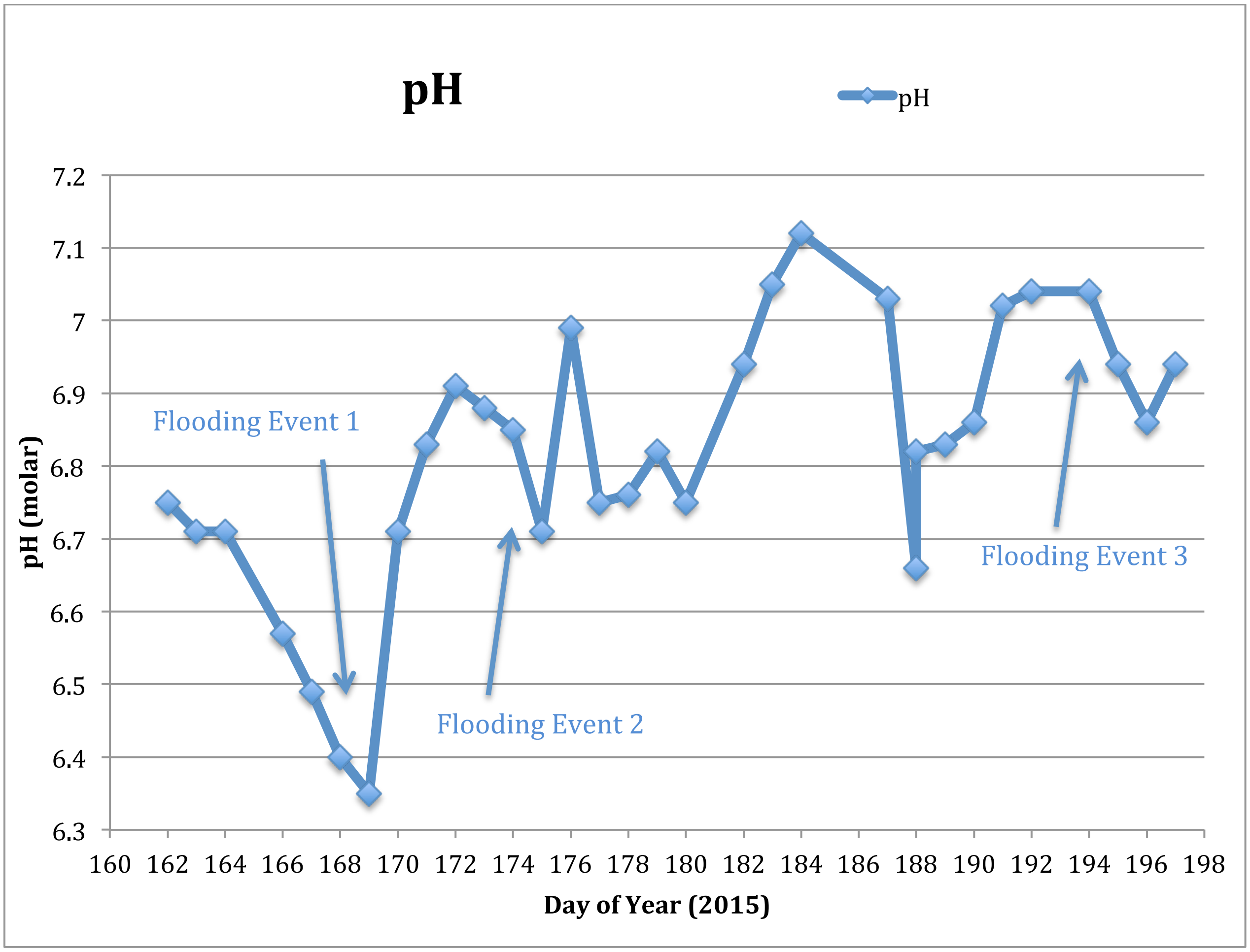

Figure 10. pH values at ORWRP from June 11th, 2015 to July 16th, 2015.

The pH values seem to be negatively correlated to the amount of water present in the wetland. After each of the three main flooding events, the pH decreased. The water in the wetland never reached a pH above 7.12, which is near neutral. The most acidic the water in the wetland ever reached was 6.35, which occurred shortly after flooding event 1. The wetland did not take very long for it to stabilize back to its neutral base state, returning to values of around 6.9 (+/- 0.20). The pH values did not take longer than one sampling period for it to return to its base state values.

DISCUSSION

Hydrological Connectivity between the Wetland and the Olentangy River

The created urban mitigation wetland at the ORWRP is adjacent to the Olentangy River, and this is an ideal location, because river water can be easily diverted into the wetland. These river diversion wetlands are located on river floodplains and are fed primarily by flooding water from the main channel of a river, which allows seasonal floodwaters to deposit sediments and chemicals into the wetland and for the "filtered" water to seep back into the stream (Mitsch and Day, 2006; Fink and Mitsch, 2006).

In the ORWRP, flood pulses are the result of the Delaware Dam releasing water into the Olentangy River. The water level in the Olentangy River rises, and causes the water to overflow the rivers banks and introduces water into the wetland, resulting in high water levels (Fig. 3 and 4). Flooding facilitates the exchange of nutrients and other material between rivers and their floodplains (Hernandez and Mitsch, 2007), or in this case, the ORWRP.

There were three main water release events (flooding events) that occurred at the Delaware Dam (Fig. 4). These water release events flooded the Olentangy River, and subsequently flooded the wetland (Fig. 3). This connection between the water release events at the Delaware Dam and the increases in the water level at the wetland show a hydrological connection between the Olentangy River and the urban mitigation wetland. As the Olentangy River floods, the wetland also floods. The wetland is also hydrologically connected to the Olentangy River as well. Once the water enters the wetland, it does not persist in the wetland for very long, it travels the length of the wetland and is then re-introduced back into the Olentangy River. Both wetland water level locations (Fig. 3) show that the water level in the wetland is consistent throughout. The water is not trapped to one specific location, but is free to move throughout the wetland until it is released back into the Olentangy River. The hydrological connection between the Olentangy River and the wetland is very clear.

Cl^- is a conservative element and would not be expected to be involved in any biogeochemical processes within the wetland. As such, variation in the amount of concentration of Cl^- in the wetland may be reflective of dilution from more dilute Olentangy River water. The concentration of Cl^- present in the wetland varies with the water level in the wetland (r^2=0.5, n=,

Fig. 5). After each flooding event, the concentration of Cl^- decreases. After the flooding event subsides, the concentrations of Cl^- increase again. During periods of extended "drought", the concentration of Cl^- increases until floodwater is again introduced into the wetland. This pattern of increasing and decreasing concentration relative to the water level in the wetland shows the hydroglogical connection between the wetland and Cl^-.

Biogeochemical cycling of Nutrients in the Wetland

Both NO_3^- and SO_4^{2-} are biologically important chemical species that participate in biogeochemical cycles. Similar to Cl^-, NO_3^- concentrations in the wetland were also linked to the hydrological input of Olentangy River water but showed a very rapid depletion in the wetland. During baseflow conditions, the concentrations of NO3- were very low (Fig. 6). NO_3^- levels would increase with increasing water level in the wetland and the river; however, NO_3^- concentrations would not persist for very long as indicated by a rapid decrease following a flooding event (Fig. 6). This suggests that the wetland, or organisms within the wetland are effective at reducing the concentration of NO_3^- present in the wetland water. The data show that the wetland does not have a very high concentration of NO_3^- in the absence of floodwater input, but that the Olentangy River is a signification source of NO_3^- to the wetland. This suggests that active nitrogen cycling is occurring in the wetland and NO_3^- is being fixed resident organisms, possibly via denitrification (Mitsch et al. 2005) in the wetland.

In contrast to NO_3^-, SO_4^{2-} showed evidence of biogeochemical cycling in the wetland during the late season "drought". A hydrological connection can be also made with the SO_4^{2-} concentrations in the wetland and could possibly be cycled into the sediment or reduced to H_2S by anaerobic respiration of SO_4^{2-} reducing bacteria. H_2S could then be reoxidized to SO_4^{2-} due to the nitrate reduction occurring in the wetland. After each of the first two flooding events, the concentrations of SO_4^{2-} decrease (Fig. 7). This pattern changes however after the third flood event, which can partly be attributed to a rain event. After the flood event had subsided, a seven-fold increase of SO_4^{2-} concentration was found in the wetland. The concentration of SO_4^{2-} increased from 3.09 mgL^{-1} to 23.44 mgL^{-1} (Fig. 7). Since the third flooding event was part of a particularly strong rain event, a source of SO_4^{2-} must have been mobilized in the wetland as a result of the storm, perhaps by physical mixing of wetland sediment or turbulent storm water flow through the wetland. Further evidence of this is found in the days prior to this rain event, where a particularly long "drought" occurred. The concentrations of SO_4^{2-} continually decreased each day until it reached its lowest value of 3.09 mgL^{-1} (Fig. 7). This suggests that when the rain event occurred, SO_4^{2-} produced in the wetland sediment was mobilized into the water column where it was sampled.

Sulfide and reduced sulfur compounds can be biogeochemically transformed to sulfate in low-sulfate oxic environments and thus sustain high sulfate reduction rates (Pester et al., 2012). This is the main mechanism that drives sulfate reduction in wetlands, but no evidence of this cycle was observed here. However, sulfate cycling away from where our samples were collected could explain the unusual pattern of sulfate concentrations observed in the wetland. Wetlands have been know to function as sulfate sinks and sulfate reduction may occur over long periods of time in these low sulfate environments (Pester et al., 2012). This could explain the phenomena seen with the sulfate concentrations here. The urban mitigation wetland is not particularly productive at reducing sulfate, but is acting as more of a sulfate sink. Sulfate concentrations correspond to low water levels and stronger oxidizing conditions, with seasonal peaks in sulfate concentration developing when low water levels weaken the anoxic conditions (Pester et al., 2012). The only time during the study when sulfate concentrations responded to lower water levels was after each flooding event when the wetland water level was slowly decreasing, sulfate concentrations were increasing. Depth-related differences in sulfate availability would have favored a higher contribution of sulfate reduction near the soil surface (Pester et al., 2012). This supports our conclusion that the sulfate was becoming reduced towards the sediment surface. The samples were taken at the same depth, which was in the middle of water column. Further samples would need to be taken towards the sediment floor to further conclude the wetland works as a sulfate sink.

Dissolved Organic Carbon Availability

The availability of dissolved organic carbon (DOC) is very important for the stability and health of the wetland. Wetlands are generally regarded as an ecosystem with relatively high concentrations of DOC. DOC is used as a food source for microorganisms and play a role in the carbon cycle. As plants and other types of vegetation die and start to decompose, they will eventually be broken down into DOC. Photosynthesis and subsequent decomposition of vegetation in these hydrologically dynamic wetlands generates a large amount of dissolved organic carbon (Holloway et al., 2011). Vegetation types also appeared to influence DOC accumulation in the wetlands (Thompson et al., 2009). Bacteria and other microorganisms use this decaying vegetation as a food source, and then higher trophic level organism's benefit from this DOC. Temperate marsh wetlands in general are highly productive and accumulate more organic carbon (Spieles and Mitsch, 2000). DOC is affected by the type of plant tissue, temperature influence upon microbial activity, and the hydrologic regime (Thompson et al., 2009). The more DOC that is available for microorganisms to use, the more vegetation that will be able to live in that environment.

The concentrations of DOC present in the wetland seem to be a function of the water level in the wetland. After each of the three flooding events, the concentration of DOC decreased (Fig. 8). The Olentangy River is probably not a significant source of DOC. Shortly after each flooding event had subsided, the concentration of DOC increased (Fig. 8, drought). Others have observed that organic matter decomposition increased when water levels were lowest (Thompson et al., 2009). The lower water levels shrink the volume of water where the decomposition takes place. Surface water DOC concentrations are higher than groundwater concentrations, and DOC is more reactive in surface water (Holloway et al., 2011). The concentrations are higher and more reactive in surface water because that is where the majority of the vegetation and microbes live. Surface water is the source of DOC. The largest concentrations of DOC are associated with seasonal wetlands and DOC may store in soil pore waters when these wetlands dry out seasonally (Holloway et al., 2011). The wetland at ORWRP is a seasonal wetland, so it should experience rather large concentrations of DOC. DOC may behave very similarly to sulfate ions, where the DOC may become stored in the soil pore waters, instead of being used or reduced. Wetlands are a productive environment for the accumulation of DOC, and most of them eventually become net carbon sinks (Mitsch et al., 2013).

Dissolved Oxygen and pH Changes

Dissolved oxygen is the amount of readily available oxygen for respiration. It is very important for the well being of all oxygen-breathing organisms living in the wetland and also important for the type of biogeochemical reactions that can occur. Without a suitable amount of dissolved oxygen present, these animals would not be able to survive. Scarce dissolved oxygen concentrations are one of the most understood limits to aquatic invertebrate life (Spieles and

Mitsch, 2000). Temperate freshwater marsh wetlands in general are highly productive, accumulate organic carbon, and may have lower dissolved oxygen and higher temperatures during the summer months (Spieles and Mitsch, 2000). The concentration of dissolved oxygen present in the wetland is a direct correlation to how a healthy a wetland is. The more dissolved oxygen available for respiration, the more organisms that can live in that environment.

The concentration of dissolved oxygen seems to be related to the water level in the wetland. After each of the three flooding events, the amount of dissolved oxygen present increased (Fig. 9). However, the concentration of dissolved oxygen did not persist in the wetland long. Shortly after each flooding event subsided, the concentration of dissolved oxygen decreased back to its normal base conditions. This implies that the water from the Olentangy River is rich with dissolved oxygen, so when the wetland floods, it is introduced with very high levels of DO. The Olentangy River had DO concentrations averaging 9 mgL^{-1}, which is higher than the average DO concentration for the wetland at 4.5 mgL^{-1} (Fig. 9). The organisms or the biogeochemical processes in the wetland must use up the dissolved oxygen, or it moves throughout the wetland very quickly, hence its rapid drop to base conditions (Fig. 9). Dissolved oxygen is negatively related to turbidity and the general turbulence of water near the pumped inflow may be a limit to productivity in these locations (Spieles and Mitsch, 2000; Stewart and Downing, 2008). Observations here seem to contradict these findings and the concentration of dissolved oxygen increased, rather than decreased. Wetland water samples were not taken at the inflow to the wetland, so it is possible that the concentrations of dissolved oxygen at the inflow are low, but gradually increase downgradient. Relative deficiency of oxygen at the inflow of the wetland was apparent, and is primarily a result of lower water column productivity due to rapid replenishment from the river (Spieles and Mitsch, 2000).

The pH is one direct indicator of how healthy the water is. If the pH is too acidic or basic, organic life will not be able to survive. So it is very important for a wetland to be able to maintain stable, neutral to slightly acidic pH values (pH=6-7). The pH determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals (Thompson et al., 2009).

The pH values seemed to be negatively correlated with the water level in the wetland (Fig. 10). After each of the three flooding events, the pH values dropped to a more acidic state. This implies that the water that the wetland receives from the Olentangy River is acidic in nature, or that some source of acidity, such as organic acids, may be mobilized in the wetland during floods. The pH values never reached lower than 6, which is only slightly acidic and should not inhibit the wetlands ability to function as an ecosystem. It is very promising to see the wetland "bounce" back to more stable neutral values shortly after the flooding events subsided. The pH shows that the wetland is a healthy environment and is suitable for many organisms.

CONCLUSIONS

The urban mitigation wetland at the Olentangy River Wetland Research Park (ORWRP) is functioning to remove NO_3^- from Olentangy River floodwater. This wetland was created to remove pollutants that are introduced into it from the Olentangy River floodwater. These pollutants contaminate the water resource for Columbus, Ohio, and, on a larger scale, contribute to the eutrophication and hypoxia of the Gulf of Mexico. The aquatic environment in Columbus, Ohio is susceptible to nitrate contamination, as highlighted by the summer 2015 drinking water advisory. The pollutant reducing ability of urban wetlands make them an important attribute to the overall health and stability of the water resource.

Of the nutrients investigated here, NO_3^- is most noticeably removed from the Olentangy River floodwater as it moves through the wetland. SO_4^{2-} appears to undergo some sort of hydrologically driven variation, perhaps via sediment porewater mobilization or reduction to H_2S, but our sampling regime did not allow us to confirm this. Since the wetland was a significant source of dissolved organic carbon, it is a contributor to the carbon cycle. The decay and breakdown of the organic matter in the wetland becomes a food source for microorganisms and also sinks into the sediment.

The wetland itself showed no signification shift in pH or dissolved oxygen content suggesting that it is a stable system during the time it has water, from spring to late summer. For a wetland ecosystem to be a stable habitat the wetland needs to maintain a neutral pH and have enough dissolved oxygen for respiration and biogeochemical processes.

To alleviate the eutrophication and the hypoxia in the Gulf of Mexico, and to ensure the safety of our drinking water, the freshwater resource needs its nutrient content reduced. New agricultural practices and technology will help to limit the amount of agricultural runoff and nitrate loading, but due to economic and time reasons, we cannot wait for those practices to be implemented. Instead, the introduction of mitigation wetlands along rivers in the Mississippi River watershed and in urban centers that receive agricultural runoff will lower the nutrient content being discharged into the Gulf of Mexico and our drinking water supply. This practice will also restore many of the important ecosystems that have been destroyed. Wetlands are a very important ecosystem that mitigate pollutants, contribute to the carbon cycle, and promote the growth of organic matter.

Suggestions for Future Research

This study was conducted at the created oxbow wetland at the Wilma H. Schiermeier Olentangy River Wetland Research Park. Every wetland that is created or used as a mitigation wetland should be studied to ensure that the wetland is functioning properly as a pollutant reducer. The wetlands in particular that should be studied further are the ones that have a direct correlation with the hypoxic zone in the Gulf of Mexico such as the wetlands that run along the Mississippi River.

This study only focused on the anion concentrations in the wetland and river. Further research needs to be done to see how the major cations interact in both environments. The anion concentration is only half the story, and testing the water for cation concentrations will reveal the true reactions between the different ions. Cations that are present in freshwater resources and could be contaminants in high enough concentrations are Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}

The middle of the water column was the only section that water samples were taken from. Water samples should be taken from the top and bottom of the water column to investigate is different processes are occurring at different depths. SO_4^{2-} and DOC may be more concentrated closer to the sediment surface. Soil samples will reveal the porewater concentrations of major anions and DOC.

The water samples were taken at one specific location in the wetland. This location was in between the inflow and open water sections of the created oxbow wetland (Fig. 2). Samples should be taken from the inflow, open water section, and also the outflow of the wetland to create a clear picture of the ions migration through the wetland.

Most of the water samples were taken from the wetland, while opportunistically samples were taken from the Olentangy River. Further research needs to be done in the river and create more of a baseline to base the wetland ion concentrations on. This study focused on primarily the wetland, but the Olentangy river also plays an important role in the hydrology and biogeochemistry of the created mitigation wetland.

There are many different types and kinds of vegetation that call the created oxbow wetland home. Each of these different flora will play a specific role in the ecosystem and how well the wetland mitigates pollutants. Some types of vegetation will be better at creating dissolved organic carbon and providing homes for the various types of animals that live there. Some vegetation may be better suited than others for reducing the amount of nitrate and sulfate that persists in the wetland. It would be interesting to see how each of these different plant types interacts with the wetland.

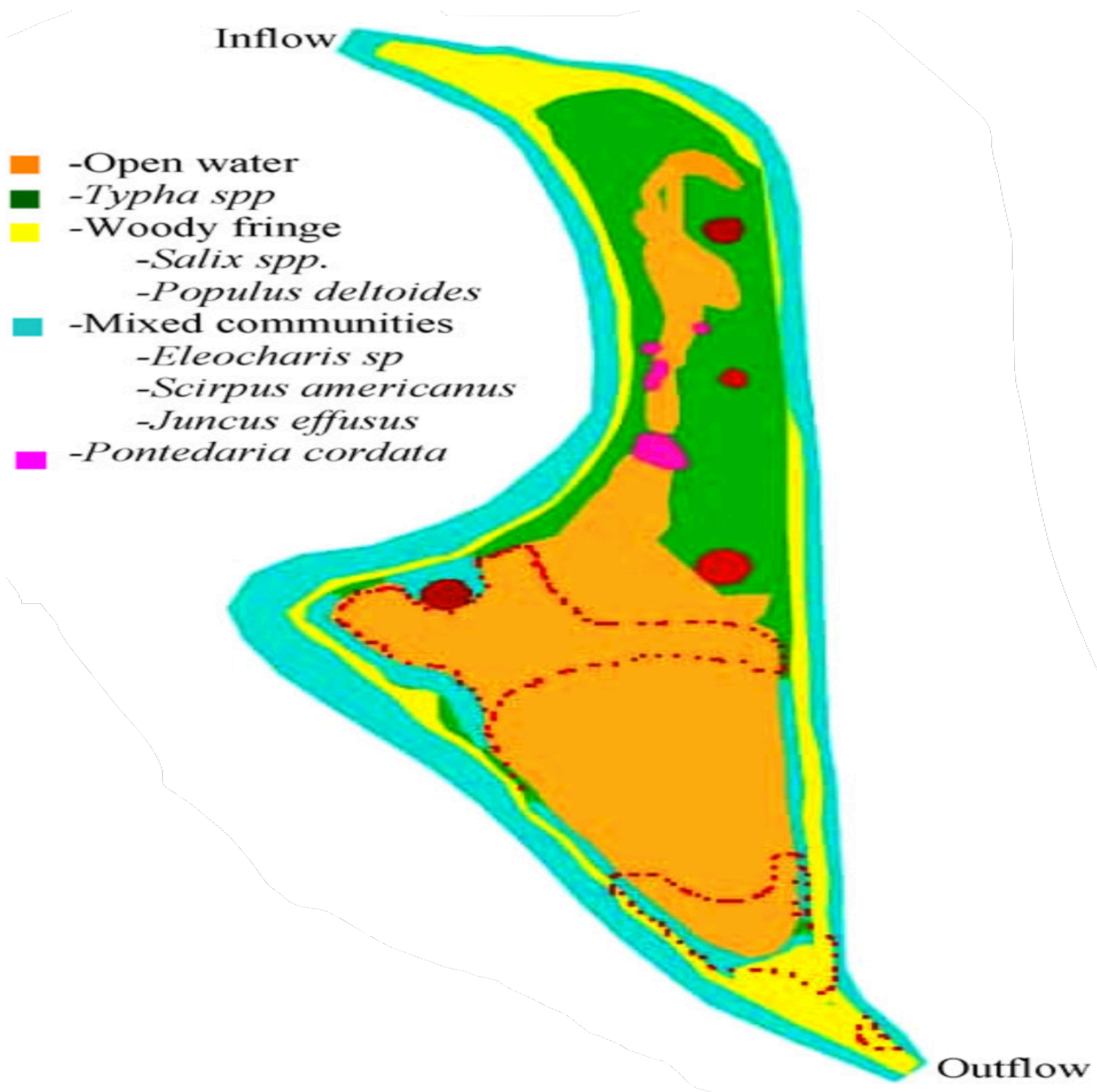

Figure 13. Cartoon showing created oxbow's different vegetation types (Fink and Mitsch, 2007).

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Appendices

Wetland Water Level and Delaware Dam Discharge

Date	Sample Water Depth (cm)	Wetland Depth Gauge (ft)	Delaware Dam Discharge (ft^3/s)
06/11/15	13.7	1.32	69
06/12/15	13.5	1.24	48
06/13/15	13.5	1.18	25
06/15/15	15.3	1.22	1390
06/16/15	18	1.32	2020
06/17/15	35	1.92	1620
06/18/15	38.5	2	87
06/19/15	34	1.84	51
06/20/15	45	2.14	62
06/21/15	35	1.82	34
06/22/15	32	1.7	387
06/23/15	27.5	1.6	2280
06/24/15	47.5	2.2	4290
06/25/15	50.5	2.3	4110
06/26/15	52	2.36	4070

06/27/15	45	2.12	2630
06/28/15	49.5	2.3	3590
06/29/15	52	2.36	3510
07/01/15	41	2.04	1320
07/02/15	47.5	2.2	2590
07/03/15	46.5	2.18	1110
07/06/15	31	1.68	175
07/07/15	33	1.7	137
07/07/15	34	1.76	137
07/08/15	32	1.74	155
07/09/15	30	1.68	461
07/10/15	28.5	1.64	456
07/11/15	27.5	1.58	190
07/13/15	27	1.58	977
07/14/15	41	2	1570
07/15/15	42	2.08	824
07/16/15	38	1.92	1140

Anion Concentrations

Values less than the detection limit (n.a.)

Date	Nitrate (mg/L)	Sulfate (mg/L)	Chlorine (mg/L)	Fluorine (mg/L)	Bromine (mg/L)	Phosphate (mg/L)	Nitrite (mg/L)
06/11/15	0.09	22.01	21.79	0.15	0.14	n.a.	n.a.
06/12/15	n.a.	15.57	21.47	0.25	0.15	0.22	n.a.
06/13/15	n.a.	10.96	20.47	0.21	0.14	0.22	n.a.
06/15/15	7.88	28.56	28.68	0.22	0.14	n.a.	0.24
06/16/15	3.80	27.16	26.97	0.22	0.14	n.a.	0.32
06/17/15	0.90	28.23	26.50	0.20	n.a.	n.a.	5.12
06/18/15	3.98	25.36	26.80	0.20	0.14	n.a.	0.18
06/19/15	1.95	23.93	26.76	0.20	0.14	0.22	0.12
06/20/15	0.18	11.34	19.14	0.17	0.14	0.23	n.a.
06/21/15	1.73	25.86	29.04	0.21	0.14	n.a.	0.06
06/22/15	0.96	25.44	30.44	0.21	0.15	n.a.	0.06
06/23/15	0.39	24.00	29.48	0.22	0.14	n.a.	0.04
06/24/15	3.51	12.08	12.74	0.17	0.13	0.25	0.04
06/25/15	3.77	15.65	16.43	0.19	0.13	0.25	0.75
06/26/15	3.99	16.18	16.26	0.18	0.13	0.26	0.08

06/27/15	2.67	22.18	24.61	0.20	0.14	0.24	0.03
06/28/15	3.86	19.16	19.43	0.05	n.a.	0.25	0.06
06/29/15	3.91	19.47	19.15	0.20	0.14	0.26	0.09
07/1/15	2.18	25.84	27.23	0.22	0.14	0.23	0.03
07/2/15	3.17	24.51	24.26	0.21	0.14	0.25	0.04
07/3/15	3.23	23.50	23.00	0.21	0.14	0.23	0.03
07/6/15	0.28	18.06	25.75	0.25	0.15	n.a.	n.a.
07/7/15	0.16	14.49	23.37	0.22	0.14	0.22	n.a.
07/7/15	0.15	14.72	22.53	0.21	0.14	n.a.	0.01
07/8/15	0.12	12.62	30.22	0.22	0.16	n.a.	n.a.
07/9/15	0.11	9.43	27.14	0.05	0.15	n.a.	n.a.
07/10/15	0.10	7.70	27.68	0.23	0.17	0.22	n.a.
07/11/15	0.11	5.89	24.97	0.24	0.17	n.a.	0.01
07/13/15	0.11	3.09	26.52	0.23	0.17	n.a.	n.a.
07/14/15	1.65	25.44	26.53	0.22	0.16	n.a.	0.05
07/15/15	0.72	21.79	25.77	0.20	0.17	n.a.	0.03
07/16/15	0.32	20.24	27.84	0.21	0.16	n.a.	0.02

Dissolved Organic Carbon, Dissolved Oxygen, and pH

Date	DOC (mg/L)	DO (mg/L)	pH
06/11/15	9.26	7	6.75
06/12/15	13.248	6	6.71
06/13/15	14.245	4	6.71
06/15/15	9.203	5	6.57
06/16/15	9.78	4	6.49
06/17/15	7.823	6	6.4
06/18/15	8.509	2	6.35
06/19/15	8.985	3	6.71
06/20/15	11.041	4	6.83
06/21/15	9.614	5	6.91
06/22/15	9.748	4	6.88
06/23/15	10.438	4	6.85
06/24/15	8.493	7	6.71
06/25/15	8.676	7	6.99
06/26/15	8.998	6	6.75
06/27/15	8.769	4	6.76
06/28/15	9.43	5	6.82
06/29/15	9.401	6	6.75
07/1/15	9.106	5	6.94
07/2/15	9.819	6	7.05
07/3/15	9.528	5	7.12
07/6/15	10.234	6	7.03
07/7/15	11.186	4	6.66

07/7/15	10.806	3	6.82
07/8/15	11.585	3	6.83
07/9/15	11.901	3	6.86
07/10/15	12.53	2	7.02
07/11/15	13.358	3	7.04
07/13/15	11.905	3	7.04
07/14/15	9.089	5	6.94
07/15/15	9.114	3	6.86
07/16/15	9.705	4	6.94